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BIOLOGICAL NUISANCE PROBLEMS. SUPPLEMENT E TO PUBLIC HEALTH ASPECTS OF PROPOSED SALT WATER BARRIER AND LAND RECLAMATION PROJECTS, SAN FRANCISCO BAY

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

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BIOLOGICAL NUISANCE PROBLEMS

SUPPLEMENT E

TO

PUBLIC HEALTH ASPECTS OF PROPOSED SALT WATER BARRIER AND LAND RECLAMATION PROJECTS, SAN FRANCISCO BAY

PREPARED FOR

U.S. ARMY ENGINEER DISTRICT, SAN FRANCISCO

CORPS OF ENGINEERS

COMPREHENSIVE SURVEY OF

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Robert A. Taft, Sanitary Engineering Center
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FOREWORD

The material presented in this Supplement represents a phase of the report of the Public Health Service to the U. S. Army Engineer District, San Francisco, California, on the Public Health Aspects of the Comprehensive Survey of San Francisco Bay and Tributaries, authorized by Section 110 of the River and Harbor Act, approved 17 May 1950 (Public Law 516, 81st Congress, 2nd Session).

Details of illustrations in this document may be better studied on microfiche.

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A. Figs. 1,2,3 from: Palmer, C. M. and C. M. Tarzwell, "Algae of Importance in Water Supplies", Public Works (reprinted from June issue), 8 pp. and 6 plates (1955).

B. Figs. 4,19,20 from Mackenthun, K. M., "The Chemical Control of Aquatic Nuisances", Committee on Water Pollution, Madison, Wisconsin, 64 pp. (1958).

C. Figs. 7,8,9 from: Ingram, W. M., "Asiatic Clams as Potential Pests in California Water Supplies", Journ. American Water Works Association Vol. 51:3 p. 363 (March, 1959).

D. Figs. 10,11 from: Wallour, D. B., "Eleventh Progress Report on Marine Borer Activity in Test Boards Operated During 1957", W. F. Clapp Labs., Inc., Duxbury, Mass. 64 pp. (1958).

E. Fig. 13 from: Edmondson, C. H., "Reef and Shore Fauna of Hawaii", Bernice P. Bishop Museum Spec. Pub. 22, 295 pp.(1933).

F. Figs. 14,18 from: Anon., "Data Book, San Francisco Bay Study", U. S. Army Corps of Engineers, San Francisco, California 17 pp.; 36 exhibits, 12 tables (1958).

G. Figs. 15,16 from: Edmondson C. H. and W. M. Ingram, "Fouling Organisms in Hawaii", Occasional Papers, Bernice P. Bishop Museum, Vol. 14: 14, pp. 251-300 (1939).

Illustrations, not credited above, were prepared from materials in the possession of the Public Health Service.

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INTRODUCTION

1. PURPOSE.

The U. S. Army Engineer District, Corps of Engineers, San Francisco, California is conducting a Comprehensive Survey of San Francisco Bay and Tributaries. This survey is generally known as the San Francisco Bay Study.

The purpose of this supplement is to indicate to the Corps of Engineers the effect of biological nuisances upon the area under consideration.

2. OBJECTIVES OF REPORT.

The objectives of this report within the period (1965-2015) of the Study is to evaluate:

a. The extent to which biological nuisances will occur in the water resources of the Study Area.

b. The effect of these biological nuisances upon water resources considered for multiple uses.

c. Control of these biological nuisances within a reference frame of the intended use of the water resources involved.

3. SCOPE OF REPORT.

The scope of this report is to investigate the problem of biological nuisances and adequately answer the questions posed by the objectives of the report. These include:

a. The evaluation and classification of biological nuisances in the Study Area at the present time.

b. Estimate of biological nuisances which may be encountered in the fresh water pools impounded by any of several proposed barrier systems.

c. The effects of nutrients on the production of biological nuisances.

d. Methods of control of biological nuisances.

4. SUMMARY.

Fresh water and marine biological nuisances will steadily increase

in the physical basin that contains San Francisco Bay. Such nuisances will interfere with multiple water uses that may relate themselves to the Bay, with or without the proposed barriers.

If the proposed barrier pools are to be used as a potable raw water source, biological nuisances, as algal blooms, can be expected to develop that will interfere with water treatment installations through the clogging of rapid sand filters necessitating frequent backwashing and the concurrent expenditure of finished water to waste in performing this function. Too, tastes and odors that will develop from algal nuisances will necessitate the institution of control measures that will minimize the carry-over of undesirable flavoring substances into finished water.

In the proposed barrier pools the development of nonemergent aquatic plants will interfere with water contact sports such as swimming, water skiing and small craft recreation. These plants will especially flourish in shallow water. Such aquatic weed beds will necessitate that control measures be maintained at recreation beach areas and at small craft inshore navigation channels and at dockage sites. In the open Bay problems of this nature will not develop because of the absence of nonemergent plant species.

Shore line accumulations of algal masses, blown into lee areas by winds and carried by currents and tides, will become offensive as they decay, to shore line habitants with or without the proposed barrier system.

Asiatic clams, now established in the fresh water of the Delta Area, that have been reported as interfering with Tracy Pumping Station operations, will spread into fresh water barrier pools. Difficulties arising from their presence will be associated with pumpage of water through channels of irrigation projects and of water treatment installations.

Without the proposed barriers in the marine and brackish water Bay, nuisances resulting from boring and/or fouling organisms will become magnified through increased numbers of small craft, dock sites, commercial ships, and shore line bulkheads. Marine borers can be minimized by employing impenetrable materials in constructing underwater structures and small craft hulls. Fouling organism difficulties can be minimized by hull maintenance and employment of antifouling paints.

Control measures for biological nuisances in the Study Area, with or without the proposed barriers, will have to be instituted with careful planning in order to assure maximum protection for humans, crops, stock and fish and wildlife resources, particularly if pesticides are used. Several courses of action to control biological nuisances are available to those who will be charged with the management of Bay waters. Multiple uses to which the waters are put will dictate various types of remedial or preventative measures that can be instituted to control biological nuisances. Control measures that can be selected from, or better used in some combination, are algicide and weedicide application, land reclamation,

mechanical cutting and raking of weeds, and physical location of water intake structures, pumping stations and recreation areas.

5. CONCLUSIONS.

a. Biological nuisances can be minimized by placing priorities on uses that have the greatest realistic potential development.

b. With fresh water pools behind barriers offering their potential for an increased variety of water uses, a greater number of biological nuisance problems will exist than for the marine and brackish waters of the present Bay.

c. Shallow pools should not be considered as suitable for raw water sources for potable supplies. Such pools will foster maximum development of biological nuisances that will interfere with the production of a satisfactory finished water for the consumer. Biological nuisances will also be associated with deeper pools, as algal blooms are carried into them by drainage from the Central Valley.

d. Biological nuisances will steadily increase in either the salt water Bay or in fresh water pools behind barriers into 2015 and 2065. Even with municipal sewage and industrial wastes intercepted and removed from the physical Bay, storm water runoff and agricultural drainage will tend to succor plant and other nuisances that are directly related to algal food chains.

e. If various pesticides are employed to control biological nuisances great care must be exercised in their use so that there is no danger of residual or direct toxicity for humans, stock, crops, and fish and wildlife.

f. Obviously marine borers and fouling organisms will be reduced if the greater part of the Bay is removed from them by the proposed barrier construction, thus creating a fresh water environment in which they cannot survive. Vice versa, if the Bay remains without barriers, and continues to exist as a marine brackish water body, fresh water biological nuisances will be minimized. However, these will increase in the Delta Area where water is kept fresh by salinity control measures.

BIOLOGICAL NUISANCES

6. GENERAL.

Biological nuisances in water have especially plagued man as metropolitan areas developed, and with them the need to use water for multiple purposes. Uses to which a body of water can be put, with aquatic nuisances relating in some degree to each use, are: drinking, stock watering, irrigation, fish and wildlife propagation, municipal and industrial waste disposal, commercial shipping, and recreation in its various forms such as swimming, boating, water skiing and aquaplaning. These uses are, and will continue to be, of vital concern to the vested interests in the waters of San Francisco Bay with or without barriers. The order of magnitude of biological nuisances, that will vary in severity to different water uses, will have to be realized by those charged with water management, so that nuisances can be minimized in placing priorities on uses that have the greatest realistic potential development.

7. ALGAE AND NONEMERGENT PLANTS.

Biological nuisances that are especially troublesome to man (excepting insects), in interfering with various water uses are caused by profuse growths of fresh water or of brackish and salt water plants. For example, some troubles they cause are: taste and odors in drinking water, clogging of filters of water treatment installations, formation of odoriferous deposits on shorelines, choking of irrigation channels, and interference with small boat maneuverability in shallows. Plants become especially pestiferous in fresh bodies of water because of a greater variety of them and because there are a greater variety of demands on such water. Plant nuisances, that will interfere with various water uses, are commonly nurtured by municipal and industrial waste effluents carrying nutrients. Nutrients that serve as water plant fertilizers are also carried into water by land wash. Plant nuisances that are considered here are those caused by algae (Figs. 1,2,3) and by nonemergent plants (Fig. 4).

Algal forms that commonly cause nuisances in open or marginal water are free-floating or weakly swimming photosynthetic plants which as individual colonies or as single cells are typically microscopic. They are referred to as plankters. When they occur in great abundance, often coloring the water green, bluegreen or brown, they are referred to in the water works field as algal or plankton blooms. Also making up a part of such blooms are bacteria, single-celled protozoans, rotifers, and small crustacea. Plant plankton in the strict sense is referred to as phytoplankton, while animal plankton is called zooplankton. Correctly, zooplankton and phytoplankton form "plankton blooms". Other algae may form filamentous or bulky growths that are attached to the bottom along shore line areas or are loosely associated with it as a habitat resting place. Certain algal filaments may form a portion of plankton blooms.

Nonemergent water plants that are considered here belong to the

higher, flowering plants consisting of the sole salt water one, eelgrass, Zostera marina, and a great variety of fresh water ones. Thus the nonemergent plant nuisances are multitudinous in fresh water, while they are practically nonexistent in salt water. The term nonemergent, as used here, refers to plants that are submerged or to ones that may have leafy parts emersed on occasion. Examples are Ceratophyllum or Coontail, Myriophyllum or Water Milfoil, Elodea (Anacharis) or Waterweed, Vallisneria, or Wild Celery (or fresh water "Eelgrass") and Potamogeton or Pondweeds* (Fig. 4).

8. FILAMENTOUS SEWAGE BACTERIUM.

The filamentous Sewage Bacterium, Sphaerotilus, (Figs. 5,6) is a fresh water organism of nuisance potential to fishing and water treatment interests. In entering water treatment installations it can effectively clog rapid sand filters. It can interfere with commercial fishing by clogging nets and with sports fishing casting and with line and reel maneuverability. These organisms form gelantinous plume like flocs that may commonly be from 3 to 6 inches long and an inch or two across. They are greyish or milky white in color, but on occasion may be tinged red or brown depending upon the nature of industrial wastes with which their growth is associated. They are capable of high efficiencies in utilizing carbonaceous foods to attain apid growth. Sphaerotilus flocs especially develop in abundance in flowing water from attached, holdfast cells from whence the flocs break off to be carried downstream in currents.

9. ASIATIC CLAMS.

Another fresh water organism that is already established as a pest in condenser cooler units in the Tracy Pumping Station of the Central Valley Project is the Asiatic Clam, Corbicula fluminia (Figs. 7,8,9). These calcareous, hard shelled clams commonly may attain, in growth, half the size of a golf ball or larger. The shell has distinctive corregated markings (Fig. 7), and is greenish, brownish-green or brown in color. These bulky shells, in accumulating by the hundreds and thousands in pipes and channels, interfere with even the best designed hydraulic conduit systems. These clams are plankton feeders, thus when fresh waters become richer in blooms from the fertilizing effects of man discarded wastes, Asiatic clams will become more abundant. These clams appear to be tolerant to a reasonable amount of organic pollution from municipal sewage. Of course, if pollution becomes bad enough they can be wiped out or reduced in numbers, as will most water life.

10. BORING AND FOULING ORGANISMS.

Nuisance organisms that are confined in damaging hordes to sea and

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*May be considered an emergent group, but since some of their leaves are invariably submersed they are mentioned here.

brackish water are boring and fouling organisms. The boring animals are worm like clams called Shipworms (Fig. 10), Teredo and Bankia, for example, and the crustacean isopod or Gribble, Limnoria (Fig. 11). Shipworms can attain a length approaching one foot; burrows caused by Bankia in piles may reach a depth of 3 feet and a diameter of seven-eights of an inch (Fig. 12). On the other hand the Gribble is a small creature with a body length of 3 mm and a width of from 1.0 to 1.5 mm. At Tiburon a single square inch of infected Douglas fir was found to contain 161 adults and 221 young in various stages of development. These small crustaceans, through their burrowing attacks into pile underwater structures, can give such structures the appearance of bath sponges (Fig. 13).

It is reported in 1942 that Teredo navalis, which was introduced into the San Francisbo Bay Area about 1913, caused a loss to exposed marine structures through boring activities of at least $25,000,000 in a few years.(1) * Another estimate of damages made in 1927 states that marine borers, including the Teredos and the Gribble, caused more than $15,000,000 worth of damage to underwater structures in two years in the reach from the upper part of San Pablo Bay (Fig. 15-C) to Antioch (Fig. 15-E).(2)

Fouling organisms (Figs. 16,17) consist of a hoard of sessile attached animals such as Barnacles, Sea Squirts or Turnicates, Bryozoans or Moss animals, and Calcareous Tube Forming Worms, etc. These animals attach themselves to any readily available underwater solid surface such as boat bottoms, ship hulls, piling and bulkheads. They are, of course, of greatest nuisance to the boat owner and to shipping interests who must constantly scrape them from hulls by beaching or drydocking. It is well known that in attaching to ship bottoms their added weight, which over some time can amount to great tonnage on a good sized ship's hull, decreases speed and maneuverability, increases fuel and wear and tear on engines through the resistance offered by the fouling mass, and increases time spent in dry docks. In efforts to repel fouling organisms repellent toxic paints with varying degress of success have been developed. Interest in repellents began early, for prior to 1867 more than 300 patents had been applied for in England, and more than 160 patents had been granted prior to 1922 in the United States. The ingredients of antifouling preparations range from the ridiculous to the sublime, from garlic to tobacco juice and from arsenic to mercury.(3) The United States Navy has conducted research for many years on antifouling paints to find more and more effective ones as new toxic chemicals come on the market.

The fouling organisms are plankton feeders. Thus, as such forms become more abundant, using discharged human wastes as fertilizers, they will be followed in parallel abundance by the foulers. Ships and small craft especially become fouled in harbors while they are at dockage.

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*Numerals in parenthesis refer to corresponding items in the Bibliography at the end of the Supplement.

Thus bays and harbors form foci for the attachment of fouling organisms.

11. THE EFFECTS OF NUTRIENTS ON NUISANCE ORGANISM PRODUCTIVITY.

Data that relate themselves to extensive plant growths show that organic nutrients, containing nitrogen and phosphorus, are among the major factors that influence plant abundance. In turn, as planktonic blooms become abundant, food is provided to nurture certain animal nuisances as fouling organisms and Asiatic clams.

In modern waste treatment practices dissolved inorganic or mineral constituents of municipal sewage and industrial wastes are removed only incidentally by sedimentation and oxidation. Also certain organic materials are broken down with treatment to liberate inorganic nitrogen and phosphorus, thus making them more available as fertilizers for plant growth. Treatment plant effluents may actually contain more readily available nutritional substrates than are found in raw sewage effluents. Thus, in order to prevent the fertilizing effect of sewage and of certain nontoxic industrial wastes and attendant nuisance problems, all such wastes should be excluded from natural lakes and impoundments.* In spite of exclusion of nutrient bearing wastes, agricultural drainage carrying nitrogenous and phosphorus compounds, will especially provide nutrients that may encourage nuisances.

12. PESTICIDE CONTROL OF NUISANCES.

Pesticides that can control various water nuisances should be used judiciously, realizing that various ones may have a toxicity for man, stock, crops and fish and wildlife. In nonemergent plant control, mechanical cutting and raking devices are to be preferred over control by weedicides. Thus any chance of chemical toxicity is eliminated.

13. EFFECTS OF LAND RECLAMATION ON NUISANCE ORGANISMS.

Existing shallows and tidal flats allow for maximum development of nuisances, especially nonemergent plants whose growth is limited by the depth of light penetration. These same areas with slightly higher temperatures can trigger algal blooms which will serve as a foci for inshore development of more intense algal growths, especially in Suisun, San Pablo, and South San Francisco Bays (Fig. 15). Fresh water shallows will also form optimum development areas for Asiatic clams.

Figure 18 is a map of the Bay Region showing the areas susceptible to maximum probable reclamation. Land reclamation would eliminate extensive shallow areas, thereby reducing favorable habitat for both non-

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*See page 10.

emergent plants and planktonic algae. Reduction of bottom areas in fresh waters will likewise reduce the habitat for the Asiatic clam. Sphaerotilus problems should not be noticeably affected by reclamation. Eliminating shallows in salt water will have little effect on reducing fouling organisms and borers. In general the reduction of biological nuisances will be most pronounced in fresh waters, principally because the nuisance producing organisms affect a greater number of both water uses and population.

Table I shows the water areas before and after reclamation for various barrier plan proposals.

TABLE 1

BARRIER PLAN WATER AREAS - SAN FRANCISCO BAY, EXCLUDING DELTA, AT MHHW UNDER PRESENT CONDITIONS AND WITH MAXIMUM PROBABLE RECLAMATION*

San Francisco Bay Study

Barrier Plan	Water Area Present Condition (acres)	Water Area After Maximum Probable Reclamation (acres)
Chipps Island	2,900	2,900
Dillon Point	33,900	20,600
Pt. San Pablo	114,100	48,500
Reber Plan	243,500	110,100
Savage Plan	270,500	120,300
Candlestick Point	100,900	37,300

*1958. Data Book San Francisco Bay Study, U.S. Army Corps of Engineers, San Francisco, California, 17 pp., 36 Exhibits, 12 Tables (Jure 1, 1958).

14. NUTRIENTS AND ALGAE PRODUCTION.

a. Sewage and industrial wastes. Domestic sewage and certain industrial wastes containing nitrogen and phosphorus provide the principal and essential nutrients to stimulate algal nuisances in the marine Bay and in the brackish and fresh water portions of the upper Bay (Fig. 15, D-E). Such wastes when discharged into the South Bay (Fig. 15, A) supply nutrients to support prolific algal blooms which in turn die and recycle their organic and inorganic contents back into already overly rich waters.

As previously pointed out, conventional complete treatment of sewage and similar industrial wastes does little to reduce the total nitrogen and phosphorus in raw wastes. To date no practical and economical way has been found to remove such constituents from treatment plant effluents. Thus, an increasing population and anticipated industrial expansion can only be expected to magnify an already serious situation. Therefore, the only practical solution for eliminating this source of nutrients that especially foster plant nuisances is removal of the wastes themselves.

Based on the investigations by Sawyer and Lackey[4], of the Wisconsin lakes, conclusions were drawn for the area that lakes showing an excess of 0.01 ppm of inorganic phosphorus and 0.30 ppm of inorganic nitrogen at turnover time in the spring could be expected to generate algal nuisance forming blooms. The significant facts collected show how low the critical level of these substances can be.

Domestic sewage may vary in its nitrogen content from 15 to 35 ppm and in phosphorus from 2 to 4 ppm. Sewage is becoming richer in phosphorus every day through the addition of synthetic detergents, 1,200,000,000 pounds being disposed to waste in 1950. Chemical and Engineering News[5] predicted a potential consumer market for the current population of the United States of some 2,500,000,000 pounds a year. Rudolf's[6] 1947 paper revealed that the per capita contribution of phosphorus ranged from 0.6 to 1.5 pounds per year before synthetic detergents flooded the United States market. Sawyer[7] in 1952 stated that estimates based on current use of phosphates in water softeners and synthetic detergents indicate that its average content in domestic sewage has doubled in the past six years. He comments further that because of this, smaller amounts of domestic sewage will cause undue enrichment of water than was formerly known.

Thus with populations in the Bay Area increasing from 2,681,300 persons in 1950, and with population estimates of 4,800,000 for 1970 and 15,007,900 in 2020,* serious nuisances in marine waters can be expected in many parts of the Bay unless fertilizing wastes are excluded (Table 2).

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*Department of Commerce population estimates dated 3 August 1959.

TABLE 2

ESTIMATE OF GENERAL DEGREE OF ALGAL BLOOM NUISANCES IN SAN FRANCISCO BAY WITHOUT BARRIERS*
1965-2065

San Francico Bay Study

Area	Condition
1. Chipps Island to Rivers	Minimal nuisances 2015 and 2065
2. Dillon Point to (1) above	Nuisances begin 2015 and go on into 2065
3. Point San Pablo to (2) above	Nuisances begin in 1965, bad by 2015, steadily worsen into 2065
4. Central Bay to (3) above and (5) below	1965 no change from 1959; 2015 Richmond-Alameda waterfront bad, worsening into 2065
5. South Bay	Nuisances begin in 1965, bad by 2015 and intolerable by 2065

*Based on areas of shallows and projected population densities surrounding the Bay shore.

Oswald et al.[8] published data in 1953 that can be used to emphasize algae abundance as they indicate that sewage contains all of the ingredients essential to support luxurious growths, and that from each million gallons of sewage an ultimate yield of about 2,000 pounds of algae can be obtained. This work was conducted under controlled conditions and with a fresh water supernatant. Ketchum[9] in 1951 made estimates of dry plankton produced per acre per year, based on the production of organic carbon in the sea. He converted this organic carbon production to values ranging from 0.52 to 10.35 tons of dry plankton per acre per year, using the equivalence factor suggested by Fleming[10] in 1940. His estimates are based on data from the English Channel, Long Island Sound, various localities in the Western Atlantic, Pacific Ocean off Southern California, Gulf of Maine, Barents Sea, and Helsingor Sound. He states that Riley[11], (1944) considers a value of about 3.2 tons of dry plankton production per acre per year as the best average value.

b. Agricultural drainage. Agricultural drainage containing fertilizers will continue to carry additional nutrients unchecked into the open Bay from farm land of the Central Valley. Nutrients will increase as more acres are brought into production with accompanying fertilizer applications. The pathway of this flow will eventually be into the Central Bay behind the Golden Gate. Some percentage of the nutrients will be transformed into plants and will reflect nuisance conditions in areas like Suisun and San Pablo Bays. Data that are available do not permit valid calculation of loss of nitrogen and phosphorus from applied fertilizers through surface wash into the Bay system. However, data furnished by the Bureau of Reclamation permits an estimate for 1955 of an average use of fertilizer per irrigated acre in California, to be 382 pounds, with 42 pounds of this being nitrogen and 26 pounds being P_2O_5.

15. ALGAE AND NONEMERGENT PLANT CONTROL.

a. Algae control. Currently, control methods for planktonic algal blooms in marine waters are not realistic. For example, tidal, wave or current effects in San Francisco Bay would soon dissipate algicidal control agents. Adjustment of the populace to algal enriched marine waters and their attendant nuisances will have to be made. This especially applies to those who will reside around South San Francisco Bay (Fig. 15-A).

Algae control with copper sulfate, the least expensive, most commonly used algicide whose toxicity to animals and other plants is well understood, is not practical. This compound would be ineffective as it would rapidly go into insoluble carbonates and hydroxides in coming into contact with sea water and not be effective as an algicide. New compounds that have been developed for control of gelatinous blue-green algae, as 2, 3-Dichloronapthoquinone, could be effective in sea water with adequate contact time. Field testing of this compound in Wisconsin indicates that it showed no toxicity, in the amounts applied, to green algae, higher aquatic plants, fish, or zooplankton. However, the long time effect of blue-green algal suppression through the use of this compound may be off-

set by vigorous growths of other algae and higher aquatic plants, once the blue-green algae are eliminated from the environment.

At the present time the only known effective control for preventing a continuing increase in biological nuisances in many portions of the Bay is the complete elimination of those wastes containing algal nutrients. Final disposal of such wastes to the ocean, after adequate treatment, might well be a satisfactory solution worthy of consideration.

b. Nonemergent plant control. If nonemergent plants develop to nuisance proportions in the fresh water of the Delta reach, mechanical cutters, that will rake the debris of their own making out of the water, should be employed. This type of control would also apply to the marine submergent eelgrass.* Currently there is not a great market for underwater weed cutters, and it is not realistic to project their worth even into today's market. A cost figure of a weed-cutting machine that is representative of the current price structure is $3,500.** This cutter will navigate in water of six inches and will cut to a depth of five feet, cutting a swath 10 feet wide, at a rate of four miles per hour in an average growth of weeds. It is estimated that one can clear from 5 to 20 acres per day, depending on the thickness of the weeds. A rake attachment is available which attaches to the sickle bar. This rake pushes the cut weeds to the bank where they can be collected for ultimate disposal. Nonemergent plant control by weedicides is thoroughly discussed more appropriately in relation to fresh water barrier pools on pages 26-28.

16. ADDITIONAL BIOLOGICAL NUISANCE PROBLEMS.

Data do not indicate that the Filamentous Sewage Bacterium, Sphaerotilus, and the Asiatic Clam, Corbicula fluminea are inhabitants of marine waters. Problems that they can create in fresh water have been discussed elsewhere and will be further implemented in the barrier section.

Boring organisms as the Teredinidae, Teredo and Bankia, and Wood Boring Isopods (Figs. 10, 11, 12, 13, 14) will increase in wooden structures unless increased pollution in certain areas results in septicity which will kill them. The third annual report of the San Francisco Bay marine piling investigations,(12) published in 1923,

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*Personal communication on Feb. 3, 1959 to J. T. Howell, Curator of Botany, Calif. Academy of Sciences, San Francisco, Calif. from Dr. W. Bridge Cooke of S.E.C. Marine eelgrass, Zostera marina, does not now occur within the confines of San Francisco Bay; one authentic record in 1852 shows it to have been present in the Bay in San Francisco County.

**Personal communication, City of Madison, Wisconsin.

states that of the Teredinidae, the Shipworm, Teredo navalis, in addition to flourishing in the marine environment of the Bay can survive under greatly fluctuating salinities. In such a reach experimental timbers at Crockett were so riddled with burrows that they went to pieces after three months. Teredo was also found in fresher water upstream as far as Antioch on the San Joaquin River. The critical area based on this report appears to be Carquinez Strait. Here, in certain years, the salinity was lowered sufficiently to destroy a large portion of Shipworms, and in other years, it was high enough to allow nearly a total survival. Typically, it was found that from Carquinez Strait upstream, the salinity was high enough during the summer and fall months, when stream discharge was low and salinity comparatively high, to allow survival, while Shipworms were killed off during the winter and spring months of extreme run off and low salinity. Data are not at hand to indicate the up Bay distribution of the Wood Boring Isopod. It is found in the marine waters and extends into brackish areas.

These borers will steadily increase with population expansion from 1965, 2015 and 2065 paralleling the increase of wooden structures in the Bay and the expected increase of small pleasure boats. The general degree of boring and fouling organism nuisances is listed in Table 3. If wooden hulled boats are replaced in time with metal hulls of aluminum or fiber glass, or other relatively noncorrosive alloy metals, many suitable substrates for their residences will be removed. Use of concrete rather than chemically treated wooden piling would also eliminate habitats for borers. Although more expensive initially, maintenance cost of wooden structures projected from 1965 through 2015 to 2065, could possibly make the initial higher cost of concrete structures justifiable. Specifications for underwater structures are listed in the 1923 report discussed above, including chemically treated piling, reinforced concrete cylinders and precast concrete piles or pile casings. At the time this report was written precast reinforced concrete piles had not been in use long enough to enable a judgment of their longevity. However, those that had been in place for 10 years showed no evidence of deterioration. Further, it was noted that untreated piling, in places where boring attacks are severe, lasted as short a time as from six to eight months, while in certain instances their life ranged from two to four years. Painted and batten-protected piling lasted on the average of five to eight years. Cereosoted Douglas fir piling was expected to have a life expectancy of 15 to 20 years while reinforced concrete cylinders cast in open caissons were in good condition after 12 years.

Barring critical degradation of water by pollutants, the fouling organism complex of barnacles, tunicates, bryozoans, mussels, and various other tube forming invertebrates will steadily increase in the Bay as underwater structures and ship bottoms offer more surfaces for attachment (Table 3). Various antifouling paints are available that can serve as repellents of these organisms, if proper maintenance schedules are kept. No attempt is made here to evaluate costs for such preventative measures.

TABLE 3

ESTIMATE OF GENERAL DEGREE OF BORING AND FOULING ORGANISM NUISANCES IN SAN FRANCISCO BAY WITHOUT BARRIERS*
1965-2065

San Francisco Bay Study

Area	Condition
1. Chipps Island to Rivers	Minimal or none 1965-2015-2065**
2. Dillon Point to (1) above	Minimal 1965-2015-2065
3. Point San Pablo to (2) above	Major 1965-2015-2065
4. Central Bay to (3) above and (5) below	" " " "
Richmond-Alameda	" " " "
San Francisco-Sausalito	" " " "
5. South Bay	Major 1965-2015-2065

*Based on pure marine habitat as most productive for these organisms.

**Depends on effectiveness of salinity control measures in Delta from upstream dam operations.

SAN FRANCISCO BAY WITH BARRIERS

17. GENERAL.

With the fresh water pools behind proposed barriers offering their potential for an increased variety of water uses, a greater number of nuisance problems are presented than for the brackish waters of the present Bay. Examples of additional water uses of pools over those of the salt water environment are: use as a source for potable water, irrigation water, and stock water. Such water uses would become quite intimate to all Bay Area residents, whereas by contrast only a relatively small percentage of the population would be involved in water usage for fishing, hunting, swimming, boating, water skiing and aquaplaning in the Bay with or without barriers. Thus, even greater emphasis must be placed on effective and adequate control of biological nuisances because of the consumption of impounded waters.

Furthermore, because of this close human contact the difficulties of control would be accentuated because of the necessity of avoiding the use of certain chemical control measures that could result in residual concentrations which would be toxic to humans, stock, agricultural crops, and fish and wildlife. Under such circumstances the prevention of biological nuisances becomes paramount. Basically this means exclusion of all possible nutrients from barrier pools. The water resources of the area will receive increasing use as the population and economy of the area expands. In spite of all possible preventive measures this increased use will inevitably result in some organic matter finding its way into the surface waters which will serve as nutrients for biological nuisance organisms. Therefore, analyses of proposed barrier plans should call for exclusion of those wastes known to contain significant quantities of nitrogen and phosphorus from barrier pools.

It should also be apparent that discharge of such materials into saline waters immediately below barrier pools will only increase the concentration of nutrients in marine areas, and accentuate algal problems in the remaining salt water portions of the Bay. From the standpoint of biological nuisances, the maximum total use of the waters of the entire Bay can best be insured by ocean disposal of domestic sewage and organic industrial wastes after necessary pretreatment to protect the marine environment of the open ocean. More detailed discussions of specific nuisance organisms and attendant control problems as related to various water uses are presented in the following sections.

18. FACTORS AFFECTING BIOLOGICAL NUISANCES.

a. Algal and other plant growths. Barrier pools will afford ideal environments for the production of prolific algal blooms and nonemergent plants. As was pointed out in discussing the Bay without barriers, sewage and industrial wastes discharging into pools will provide nutrients

essential for algal growth, as will runoff from agricultural areas. The waters of the Sacramento and San Joaquin Rivers will likewise bring additional nutrients both from agricultural drainage and waste effluents in their respective drainage basins.

The creation of the fresh water impoundments will also promote rather than retard algal blooms. Impoundment will increase water temperatures over present conditions and the extensive shallows in Suisun, San Pablo and South San Francisco Bays will provide ideal areas favorable for algal propagation. These same shallow pool bottoms contain the rich organic nutrients that have accumulated over thousands of years. Thus, even without benefit of man's nutrient containing wastes, these areas should support seasonal blooms of algae and luxuriant growths of nonemergent plants. For these reasons, land reclamation (Fig. 18) would be especially effective in reducing biological nuisances in the shallow areas of fresh water pools.

The nonemergent aquatic plant flora that will develop in the pools in shallower areas will become abundant in individuals and species. This flora should begin to make good headway several years after fresh water has replaced the marine environment. It is pointed out in "Flora of the Marshes", by Herbert Mason,(13) that the more rapid changes (in plant biota) found in fresh-water marshes may possibly be the result of the much larger number of species available to and capable of entering into a fresh-water succession. In contrast, there are relatively few species of flowering plants available that can tolerate the conditions found in salt and brackish water habitats. A continual unobstructed water pathway for the migration of a variety of nonemergent aquatic plants into fresh-water barrier pools, especially Dillon Point and Point San Pablo (Fig. 15 D-C), exists in the form of the Sacramento and San Joaquin drainage. Seeds and fruits of such plants carried downstream into these barrier pools, where they will settle and germinate, will be an every day occurrence. Beds of submerged aquatics provide a haven for survival of young fish and are related positively to water fowl propagation. However, these underwater growths will interfere with anglers by becoming entangled on lines, with recreation beach areas, and with small boats. Thus a pressure to control them in restricted areas will be constant.

The predicted nuisance conditions at the various barrier pools from algae and nonemergent vegetation are given in Table 4.

b. Additional biological nuisances. The potential development of Sphaerotilus in the Chipps Island and Dillon Point barrier pools (Fig. 15 D-E) is great, if growth stimulating nutrients are present in wastes that enter the pools or that may be brought in from upstream sources. Mention has been made previously on page 5 of the types of wastes that favor the production of this extremely objectionable "stepchild of pollution".

No reliable estimates can be made concerning possible Sphaerotilus infestations unless nutrient rich sewage and industrial wastes are excluded from barrier pools. If such wastes are excluded, Sphaerotilus

TABLE 4

ESTIMATE OF GENERAL DEGREE OF ALGAL AND
EMERGENT AQUATIC PLANT NUISANCES
IN SAN FRANCISCO BAY WITH BARRIERS
1965-2065

San Francisco Bay Study

Area*	Condition
1. Chipps Island to Rivers	Minimal 1965-2015-2065
2. Dillon Point to (1) above	a. Minor in Suisun Bay 1965, and minor in main channel 1965-2015-2065 b. Major in Suisun Bay in 2015 and 2065
3. Point San Pablo to (2) above	Major in 1965-2015-2065
4. Central Bay to (3) above and (5) below:	
Richmond-Alameda	Minor in 1965-2015-2065
San Francisco-Sausalito	" " " " "
5. South Bay	Major in 1965-2015-2065

*For locations see Figure 15.

should not become a nuisance in any of the pools in 1965, 2015, or 2065.

Asiatic Clams, Corbicula fluminea (Fig. 7) will occupy all barrier pools (Fig. 15, A through E), and they can occupy either river, stream or lake habitats. They are plankton feeders and would develop large populations in algal laden barrier pools (Table 5). They have spread rapidly in the West Since the first collections were made in 1938 in Washington and in 1946 from Potato Slough at the terminus of the Lodi-Isleton highway in California. Today they are found both in the San Joaquin and Sacramento Rivers, in tributary drainage and in Coachella and Imperial Valleys in Southern California and in waterways in Phoenix, Arizona.

The fouling and boring organisms that are prevalent in salt and brackish water typically cannot live in fresh water, and consequently will not be a problem in barrier pools.

19. DETRIMENTAL EFFECTS OF BIOLOGICAL NUISANCES TO POTENTIAL WATER USES.

The deleterious effects and constant problems caused by the various biological nuisances have been discussed in considerable detail earlier in this report. However, it is believed desirable to remphasize how the various nuisance organisms will interfere with specific water uses that the Bay barriers themselves would create.

The use of barrier pools as a source of public water supply will create the greatest conflict of interests between the several water uses, and will also pose the most serious problem in the control of biological nuisances. Algal blooms can produce extremely objectionable tastes and odors in treated water supplies. Both capital costs for water treatment and plant operating and maintenance costs will be materially increased if essential treatment is provided. Presedimentation basins and additional chemical treatment should be anticipated. Even then, no supply exposed to serious algal blooms can expect to escape at least intermittent complaints from tastes and odors in treated water.

Particular care should be exercised in the design and location of raw water intakes in barrier pools. Deep water intakes with variable depth drawoffs would be desired, and these should not be located where wind blown algal blooms would be concentrated.

Excessive algal blooms will also be inimical to recreational uses that would normally develop in fresh water pools as well as to human habitation in close proximity to shore lines. Odor nuisances, from decaying algae that may concentrate along shore lines and recreation areas, are entirely possible, especially if sewage and other nutrients are discharged to the pools.

The deleterious effects of extensive plant growths, especially algae, on recreation and habitations, is especially well documented in reports on the Madison, Wisconsin lakes, notably Monona, Waubesa and Kegnosa. Sawyer[14] in 1947 wrote that the lakes of Madison are

TABLE 5

ESTIMATE OF GENERAL DEGREE OF ASIATIC CLAM NUISANCES IN SAN FRANCISCO BAY WITH BARRIERS 1965-2065

San Francisco Bay Study

Area	Condition
1. Chipps Island to Rivers	Minor 1965; Major 2015-2065
2. Dillon Point to (1) above	None 1965; Minimal 2015; Major 2065
3. Point San Pablo to (2) above	None 1965; Minor 2015; Major 2065
4. Central Bay to (3) above and (5) below: Richmond-Alameda San Francisco-Sausalito	None: Marine Waters
5. South Bay	None in 1965; Minimal 2015; Major in 2065

notorious for several reasons, namely: because Henry Wadsworth Longfellow once wrote a complimentary poem about them; because of the highly undesirable algal blooms which of recent years have particularly infested the lakes in the chain below the city and which have driven lakeshore cottagers away and resulted in general depreciation of their property values, and because of the large scale use of copper sulfate in algal control. Sawyer, in discussing further the Madison lakes situation, states that prior to 1884 the city had no sewage system and lakeshore residents disposed of their wastes directly to the waters.[14] In 1884 a sanitary sewerage system was begun. Disposal of raw sewage into Lake Mendota and Monona was practiced until 1899, when the first sewage treatment installation using chemical processes was placed in operation. At this time all discharges to Lake Mendota were stopped, and the treatment plant effluent was directed into the Yahara River and thence into Lake Monona. From 1902 to 1956 all sewage has been treated by some form of biological treatment, the effluent being discharged to Lake Monona. By 1918 conditions for algal growth and attendant nuisances had become so bad in Lake Monona that the Mayor and City Council of Madison hired an engineering firm to study the situation. They reported:

(1) - "all the evidence appears to show conclusively that the offensive smells from Lake Monona during the summer of 1918 were caused by algae, produced in great abundance in lake waters",

(2) - "we believe the indirect influence of sewage effluent (pop. 35,000) in stimulating algal growths to be proportionally unimportant", and

(3) - "the engineers indicated that the sewage plant effluent was only 1/20 as important as the agricultural drainage in the odor problem"

This was substantiated by two University of Wisconsin scientists.[14]

Contrary to earlier reports Lackey and Sawyer[4] in 1945 show that Lakes Waubesa, Monona and Kegnosa receive their greatest inorganic nitrogen and phosphorus nutrient supply from nonagricultural drainage. These lakes are still being studied intensively by University of Wisconsin scientists and engineers in order to arrive at a solution for the plant nuisance problems which still exist.[15,16,17] Sewage disposal practices in the Madison area have been modified since the earlier history reported above, but the aquatic plant nuisances still persist in varying degrees of magnitude, as they are still related to nutrient substrates of nitrogen and phosphorus origins from sewage and agricultural drainage. Legislative action has required that the sewage from the Madison Metropolitan Area, which is now completely treated with an effluent B.O.D. of about 15 ppm, be bypassed around the Madison Lakes. The construction of this project which was just completed in 1958 amounted to a cost of slightly over $3,000,000.

Mackenthun[18] in 1958 has written most interestingly of the general effects of plant nuisances on humans, from a background of extensive massive algal and weed control field practices in applying algicides and weedicides in various Wisconsin lakes to abate plant nuisances. He mentions that especially during hot summer periods algal blooms accumulate to give lakes a thick, green, pea soup appearance and consistency. At times of blooms lakes are no longer inviting to bathers and fishing may be impaired. Boating becomes a sport "out of season" as long as unsightly masses of green persist and vile odors produced on decomposition permeate the area. Further, he states, "There are also well substantiated reports of fatal poisoning of livestock from drinking water containing algal decomposition products.[19] Whether or not algae work a direct health hazard to humans has not been demonstrated, however, humans may at least be affected secondarily by the odors of decomposition which make life in the area hardly bearable and may necessitate changes in residence. These effects have led interested individuals to seek means of preventing and alleviating algal blooms and obnoxious odors emanating from the decay of the mass of organisms."

Odors given off by algae have been characterized as moldy, pigpen, grassy, fishy, all being disagreeable to persons. When certain blue-green forms decompose they liberate a blue pigment that may color shore lines, boats and underwater structures. This liberated pigment is often mistaken for copper salts or paint. Accumulations of extensive masses of decomposing algae in shoreline areas can be responsible for fish mortalities, for with decomposition, oxygen resources are removed from water and denied to fish and their food organisms, with the potential of catastrophic fish kills.

Copper sulfate treatment of Lake Monona for control of algal blooms and the curtailment of nuisance conditions was started in 1918 and has been used each year since. Mechanical and chemical control of luxuriant nuisance nonemergent plants and emergent ones has also been practiced.[20] The 1956 progress report on the Aquatic Nuisance Control Program from the Wisconsin Committee* on Water Pollution Control to the State Sanitary Engineer shows that in this year 16 lakes were treated with 24,689 pounds of blue vitriol (copper sulfate $CuSO_4 \cdot 5H_2O$) for algal control, and that 30 lakes were treated with 23,819 gallons of commercial sodium arsenite for weed control. Additional pesticides were also used. At an estimated cost of fifteen cents per pound for copper sulfate costs amounted to some $3,700, and for commercial sodium arsenite at an estimated cost of eighty cents a gallon to some $19,000.

Asiatic clams can cause serious problems in maintenance and operation of pumping stations, irrigation facilities, and in various pipes and conduits. Such difficulties are already being experienced in the Delta Area and can be expected to increase rather than diminish.

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*Mackenthun, K.M., Biologist, Committee on Water Pollution, Madison, Wisconsin, personal communication 1958.

Probably no one nuisance organism could have a greater potential danger to all types of water uses than the slime, Sphaerotilus. Heavy infestations can cause serious damages to all normal water uses, public and industrial water supplies, all types of recreational uses, fish propagation, and agricultural uses.

BIOLOGICAL NUISANCE CONTROL

20. PESTICIDES AND MECHANICAL HARVESTING.

Caution in using pesticides (variously called algicides, weedicides, molluscacides, insecticides), should become a byword phrase to those who would be charged with barrier pool management or with management of the brackish and marine waters of San Francisco Bay without a barrier system. Still not enough specific information is available to indicate the toxicities of many pesticides to humans, stock, fish and water fowl, and their food organisms, and to agricultural crops. In the case of nonemergent plant control, underwater cutting and raking devices, that can be designed locally, are recommended over chemical control. In deep pools as Chipps Island and Dillon Point (Fig. 15, D-E), that appear to be the best for potable raw water sources (where multiple ports can be built into deep water intake structures to select the best quality of water that may vary seasonally) most pesticides would be dangerous for biological nuisance control. There is always the danger that such might seek a stratified water layer and enter the water supply. Of course, if pesticides are innocuous to plants and animals, other than biological nuisances that they were designed to control, such could be used without subtle hazards involved. Copper sulfate when used judiciously in algal control can be one of these. The 1946 Public Health Service Drinking Water Standards,[21] in relation to copper and humans, state that copper shall not exceed 3 ppm as Cu in finished water. Dosages of copper sulfate for example, as discussed later, that are effective in algal control and have been shown to be nontoxic to fish in field applications, are commonly applied in amounts from 1 ppm downward depending on variations in alkalinities.

21. LAND RECLAMATION.

Maximum probable reclamation, if feasible, would greatly reduce shore contact with aquatic plant nuisances, in eliminating shallow flats, numerous coves and inlets, and small boat navigation channels, where vegetation would especially accumulate (Fig. 18). Thus, without reclamation, plant problems in the shallows would be maximum; they would be lessened with reclamation of land of greatest potential, and further reduced with maximum probable reclamation. With reduced water area, nutrients and other materials will become more concentrated, however, with the deepening of shore water to a two fathom mark by reclamation, penetration of sunlight will be lessened and nonemergent plants will not gain the foothold to become the nuisances that they would in the shallows over the old tidal flats and channels in certain barrier pools. (Fig. 15, A,C,D). Thus, reclamation in itself will serve as a partial control for nonemergent plants. Algal blooms will occur in surface waters of barrier pools, but with reclamation there will be minimal shallow areas into which they may be blown, to form shore line nuisances.

22. ALGAE CONTROL.

Algae control will not be practical in open barrier pools because of expense and of the futility of controlling shore concentrated blooms that can be replaced by wind action one after another. Pleasure boat yacht harbors and recreation areas that are protected by bulkheads could practice control through the application of algicides. If pools are to serve as a raw water source for a potable supply, presedimentation basins, ahead of the usual water treatment units, would permit more effective removal of taste and odor producing algae by physical and chemical pre-treatment.

In applying algicides, aquarium tests should be used to determine the proper amount to be applied. It is impossible to discuss effectiveness of all algicides that have flooded the market during the past 10 years. Copper sulfate ($CuSO_4 \cdot 5H_2O$) commonly known as blue vitriol, blue coppers, or blue stone, has been used as an effective algicide for many years (beginning about 1904 in the United States) and is still used extensively. Application of copper sulfate to small boat harbors surrounded by bulkheads and recreation areas could be done through employment of spraying devices. Dosages that are added for algae control in presedimentation basins associated with water treatment installations could be added at inlets, using the turbulence created by pumps to thoroughly mix the copper sulfate with the water.

Following contact with copper sulfate algae cells fade rapidly from pigmented hues, especially green, to greyish-white, in from 10 to 30 minutes. This color change reflects a characteristic toxic effect that indicates algae are in the process of being destroyed or are dead. Each increasing increment of alkalinity requires additional copper sulfate, thus dosage varies with the alkalinity from one body of water to the next.

Shore line problems arising from concentrated algal blooms in the upper two feet of water could be alleviated by spraying copper sulfate (Figs. 19, 20). Small boat harbors and recreation beaches would be areas in which to practice such control. Waters with a total methyl orange alkalinity of 50 ppm or greater have been treated with consistent success in Wisconsin with a commercial copper sulfate ($CuSO_4 \cdot 5H_2O$) dosage of 1 ppm calculated to be delivered to the upper two feet of water irrespective of actual depth. This is an arbitrary way of determining dosage, but is one that has been thoroughly field tested in many lakes in Wisconsin and found to be effective. The two foot depth is one that has been determined to be approximately the maximum effective range from a surface application in high alkalinity water. On an acreage basis, 1 ppm would amount to 5.4 pounds of $CuSO_4 \cdot 5H_2O$ per acre. Copper sulfate will destroy algae with increasing depth, only if the rate of downward diffusion exceeds the rate of precipitation. Algae killed by surface treatment are the common bloom formers that are found in the upper waters in calm weather.

In waters with a methyl orange alkalinity of less than 50 ppm dosage is calculated for the entire volume from top to bottom, since precipitation of the copper sulfate out of water by alkalinity is minimized. In such waters, which naturally may have fewer algal cells, a dosage of $CuSO_4 \cdot 5H_2O$ of 0.3 ppm or 0.9 lb per acre foot have been found to be effective. This dosage determination is partially predicated on the fact that it does not deliver to the bottom significant amounts of copper that could endanger bottom life. Complete treatment, as in the application of 0.3 ppm of copper sulfate, is recomended for presedimentation basins and the 1 ppm surface type for shore line control.

It should be stressed that if extensive shore line reaches of water had to be treated in recreational and boat areas, that such be handled on a strip basis, with one quadrant (a mile of shore line 200 feet in width) treated, and a three day time lapse between quadrants. Thus, if algae were particularly abundant, their decay would not be likely to lower the dissolved oxygen to asphyxial levels for aquatic life. Size of quadrants to be sprayed could best be determined after local situations have been assessed. One can expect odors to develop from killed algae, however, in the living and partially decomposing state in untreated waters, odors are also present that can be obnoxious. Killing does eliminate the contact nuisances.

23. NONEMERGENT PLANT CONTROL.

Chemical control, for the same reasons given under the discussion of algal bloom control, can be impractical. There are chemicals such as sodium arsenite and 2,4-D that are effective weedicides, that have been used in marginal areas of large lakes in several states. Dangers that are associated with them which can be eliminated, when judiciously used by trained persons, are well known, however, their application to barrier pools that also serve as potable water raw water sources, for stock water, irrigation of crops and fishing will very definitely restrict their indiscriminate use.

In huge barrier pools practiced marginal weed control could be safely conducted, using firm ground rules discussed later, without fear of contamination of water areas several miles away from which there would be withdrawn supplies for eventual potable use, irrigation and stock watering. Spraying programs using sodium arsenite, if properly managed, are not directly destructive to fish. In Wisconsin, since its use was initiated in 1939, the only fish mortalities occurring throughout the history of the program have been directly attributable to careless handling and spillage of large quantities of chemical near loading docks. No fish kills have resulted from routine weediciding following recommendations to be followed in control work.

From field testing in Wisconsin, it has been demonstrated that the amount of sodium arsenite needed for adequate weed control in a small pond of two acres should be calculated at the rate of 4 ppm of As_2O_3 for the entire volume. For ponds and lakes greater than 2 acres and less than 10, a dosage application of 5 ppm has been shown to be effective.

In large lakes, as the barrier pools, indiscriminate nonemergent weed control will prove extremely destructive to fisheries and water fowl in eliminating food productive areas, in removing invertebrates, as well as being uneconomical. Thus in managing such pools, only areas in the vicinity of boat harbors and small boat channels and designated recreation areas should be ones where weediciding with sodium arsenite should be considered. In treating such shore line areas in large lakes where there may be protection from wind and wave action, and where the average depth does not exceed 5 feet with a maximum of 8, a dosage of 7.5 ppm of white arsenic (As_2O_3) equivalent is recommended. A dosage of 10 ppm of white arsenic equivalent has been found to be effective in control of nonemergent vegetation in shore line areas of a large body of water unprotected from wind and wave action, where the average depth is 8 feet and the maximum depth does not exceed 10. The majority of large lake treatment projects will achieve maximum success when 10 ppm is used. Experience indicates that treatment of shore line areas which exceed these depths will be expensive and difficult to treat because no uniformity of diffusion in deeper water can be depended upon, which is the base of success.

Standard application of sodium arsenite is by spraying to deliver sodium arsenite to the water surface. Figures 19 and 20 illustrate a small spraying boat and larger spraying barges, respectively, that have been used in applying either sodium arsenite or copper sulfate. Spraying operations begin at the shore line and proceed into open water; this line of travel in applying the weedicide should never be reversed. Fish and many aquatic organisms are apparently repelled by sodium arsenite and are stimulated to leave the area being treated. Their escape reaction exposes rapidly moving ones to the chemical for only a short period. Safety factors are set into action almost immediately following application. These are effective in reducing the chemical concentration to which fish and food organisms are exposed. Some of the dosage is adsorbed by plants and particulate silt and mud. The original dosage is reduced within the treated area in a short period of time, and in from 12 to 24 hours it is difficult to find any of the chemical in solution in the area. Waters that are thus treated have to be monitored to determine decreases of arsenic residuals as a safety precaution.

Trees, shrubbery, grass, and flowers will be burned or killed if spray is inadvertently turned on them. This can be a result of careless handling or as a result of winds or air currents which can carry the spray shoreward. Spraying is to be avoided on cloudy, mist-laden days when the saturated atmosphere appears to combine with the chemical in the spray, resulting in severe burning of foliage. Spillage on boats, piers, and buildings should be avoided in handling the concentrated liquor before dilution for application, for it will remove and discolor paint. Any spillage of the concentrated liquor on the body should be washed off immediately.

The effect of a first treatment of weeds in a given area should be

considered to be temporary. A single treatment will initially control nonemergents for one growing season. Weed seeds that lie in mud bottoms are not affected, neither are seeds which may infiltrate the controlled area from adjacent uncontrolled nonemergent weed beds. Therefore, treatment of a given area is required for at least two successive years. After 2 or 3 years, weeds may very likely become thinned to a point where they are no longer a nuisance, thus treatment may be eliminated or reduced. The lasting success of weediciding measures is dependent primarily on the influx of seeds into the eradication area from adjoining weed beds.

The time required for nonemergent plant death and decomposition varies. During warm summer peiods in the Middle West about five days are required for plants to sink to the bottom. From ten days to two weeks or longer is required for decomposition to be consummated. This cycle varies, of course, depending on oxygen supply, temperature and bulk of plants. Ideally, killed weeds should be raked from the bottom so that in decay there is no danger of reducing oxygen supplies to critical levels for aquatic life.

Areas that are sprayed should be posted with large legible signs, similar to those that the California State Department of Health has used on coastal beaches during the "mussel poisoning" seasons. Good practice as a safety measure dictates the prevention of swimming in a treated area and to advise against use of the water for crops, lawns, livestock, domestic animals, or for any other use for a period of two days following treatment. At the end of two days sodium arsenite should be sufficiently dissipated by dilution and absorption as to make the precautions no longer necessary. Cattle and other grazing animals should not be allowed access to shore plants. It is almost impossible to conduct marginal operations without loss of chemicals to shore foliage. Stock may be attracted to such by the salty taste of the control chemical and eat enough of the treated shoreline vegetation to be poisoned.

Sodium arsenite being a caustic compound will burn if it contacts the skin and is not washed off immediately with water. Consequently, there are precautionary measures which should be taken by those who spray the chemical. A welder's face mask or some plastic shield should be used to cover the face and neck. Face cream should be applied as an added protection. Rubber gloves that are tight-fitting above the wrists should be worn and overlapped by a jacket with tight-fitting cuffs.

24. CONTROL OF OTHER BIOLOGICAL NUISANCES.

The potential development of Sphaerotilus problems has been discussed. To prevent this pestiferous growth, nutrient substrates with available carbon and nitrogen sources should be excluded. Practical control measures are yet not known to sanitary science, thus cost figures are not available. Control measures that have been attempted in the laboratory as well as in the field are intermittent discharge of wastes and biological treatment. Intermittent discharge is based on the hypothesis, that in depriving

Sphaerotilus of food for a period each day by alternating storage and discharge of certain wastes rich in nutrient substrates, starvation will reduce populations if not be effective in control. This method has not succeeded in practice in the field on a plant-sized scale. In the laboratory it has been demonstrated that with intermittent food releases, growth is minimized and slime masses disintegrate.

Asiatic Clams, Corbicula fluminea (Fig. 7), will occupy all barrier pools for their spread has already been shown to be quite rapid since the first western collections were made. They can occupy either river, stream, or lake habitats. They are plankton feeders. They would develop large populations in unpolluted waters, as behind barriers with wastes excluded, as well as in polluted water unless this latter environment had enough sludge deposits, lack of dissolved oxygen, and toxic effects to kill them.

As yet no extensive research has been done to reveal an effective molluscacide that can control these clams. A search began for an effective molluscacide in 1952 at the Tracy installation in order to rid condenser cooler units of clams. Collected data indicated that copper sulfate was effective at 750 ppm with an exposure time of 48 hours. Chlorine was found to give a quicker kill, but the required concentration (not known) was corrosive to metal, as copper sulfate would be. In 1953, 2,500 ppm of an aromatic solvent was found to be effective, stated to be safe, and relatively low in cost. The present control method is to inject approximately 2,500 ppm of coal tar naphtha plus an emulsifier into one of the 600 gpm pumps supplying water to the condenser cooler units until the effluent becomes discolored. The water is then shut off for 24 hours, after which the unit is flushed at an increasing velocity using two 600-gpm pumps. The cooler unit heads are then removed and the plugged tubes rodded. With this treatment and with use of both pumps in normal operation, the clam control problem in the condenser cooler system has been reduced. Chemical treatment is done in September or October when the condenser can be shut down, but these months do not represent necessarily the most effective time of year for clam control. Cost figures are not available for the above alleviation of the clam nuisance problems. It can be positively stated that there are still no effective molluscacides for this clam that can be safely applied to multiple purpose pools.

Asiatic clams will create minor nuisances in barrier pools in 1965 which will continue in varying severity into 2015 and into 2065 (Table 5) unless an effective molluscacide is found that can kill their larval stage before they develop a shell. Even if adults are killed by a molluscacide, this is not a remedial measure, for their shells are left behind which can only be removed by the rodding of pipes or by manual removal from channels.

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ALGAE IMPORTANT IN WATER SUPPLIES

TASTE AND ODOR ALGAE

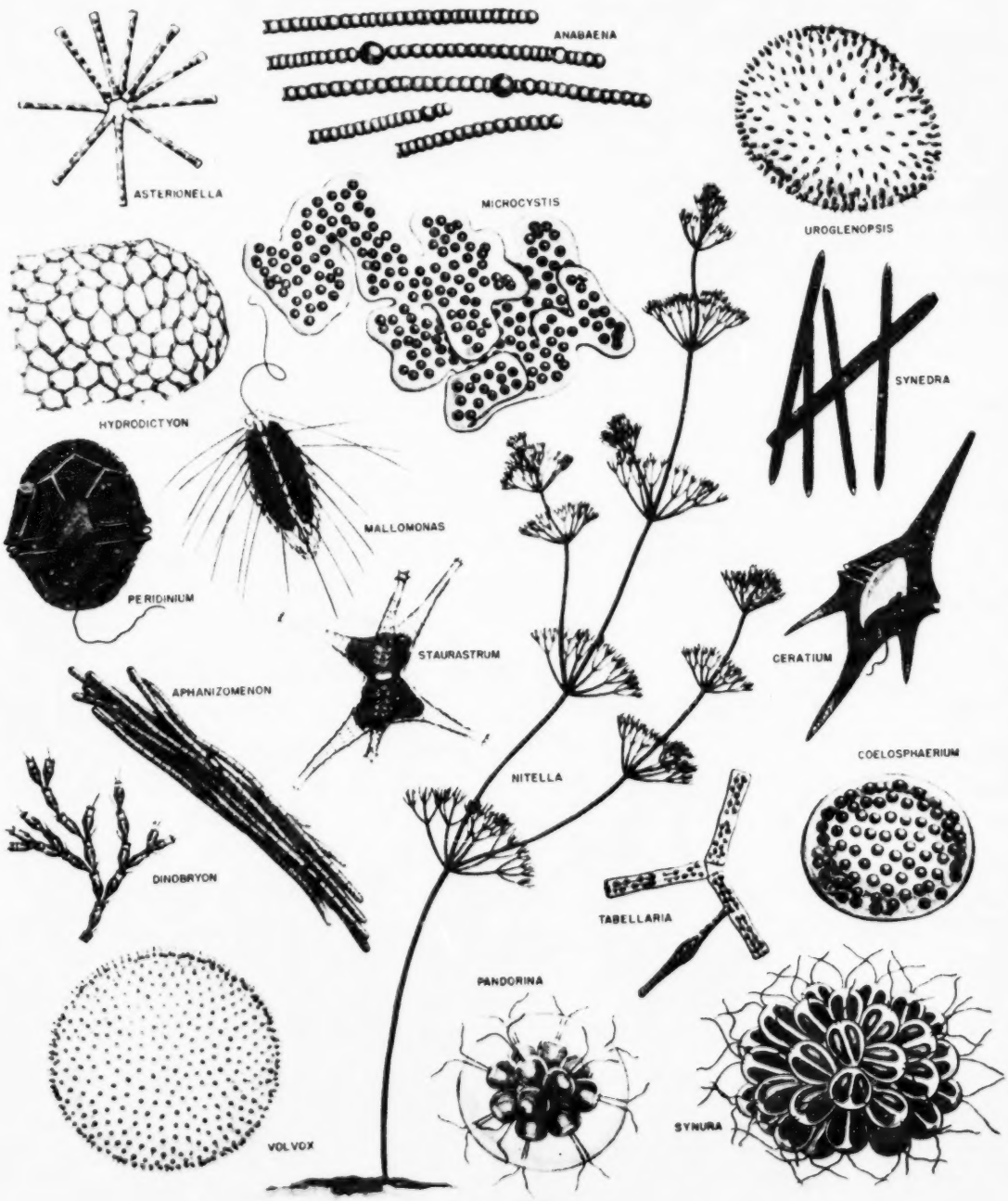


FIGURE 1

FILTER CLOGGING ALGAE

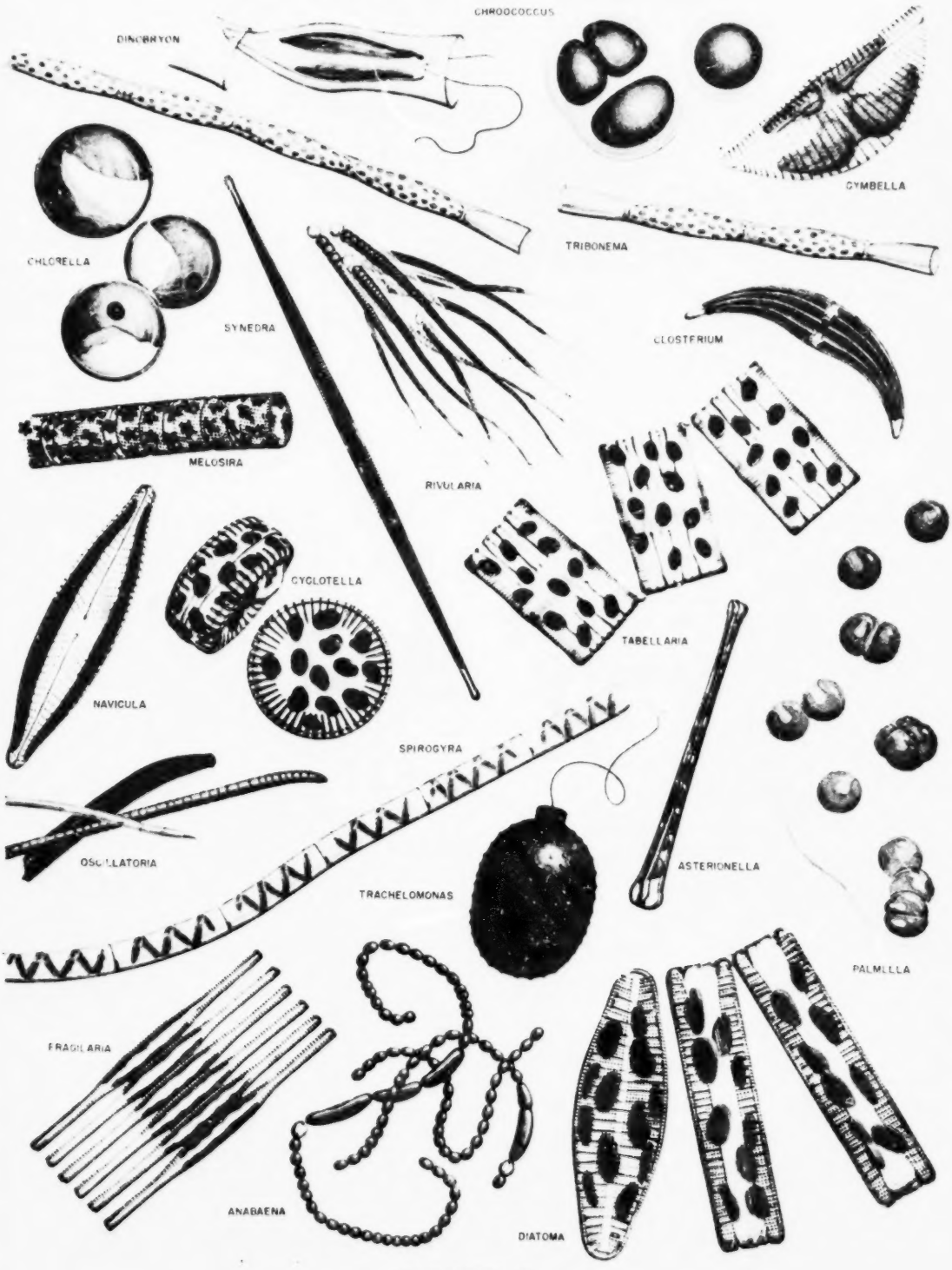


FIGURE 2

POLLUTED WATER ALGAE

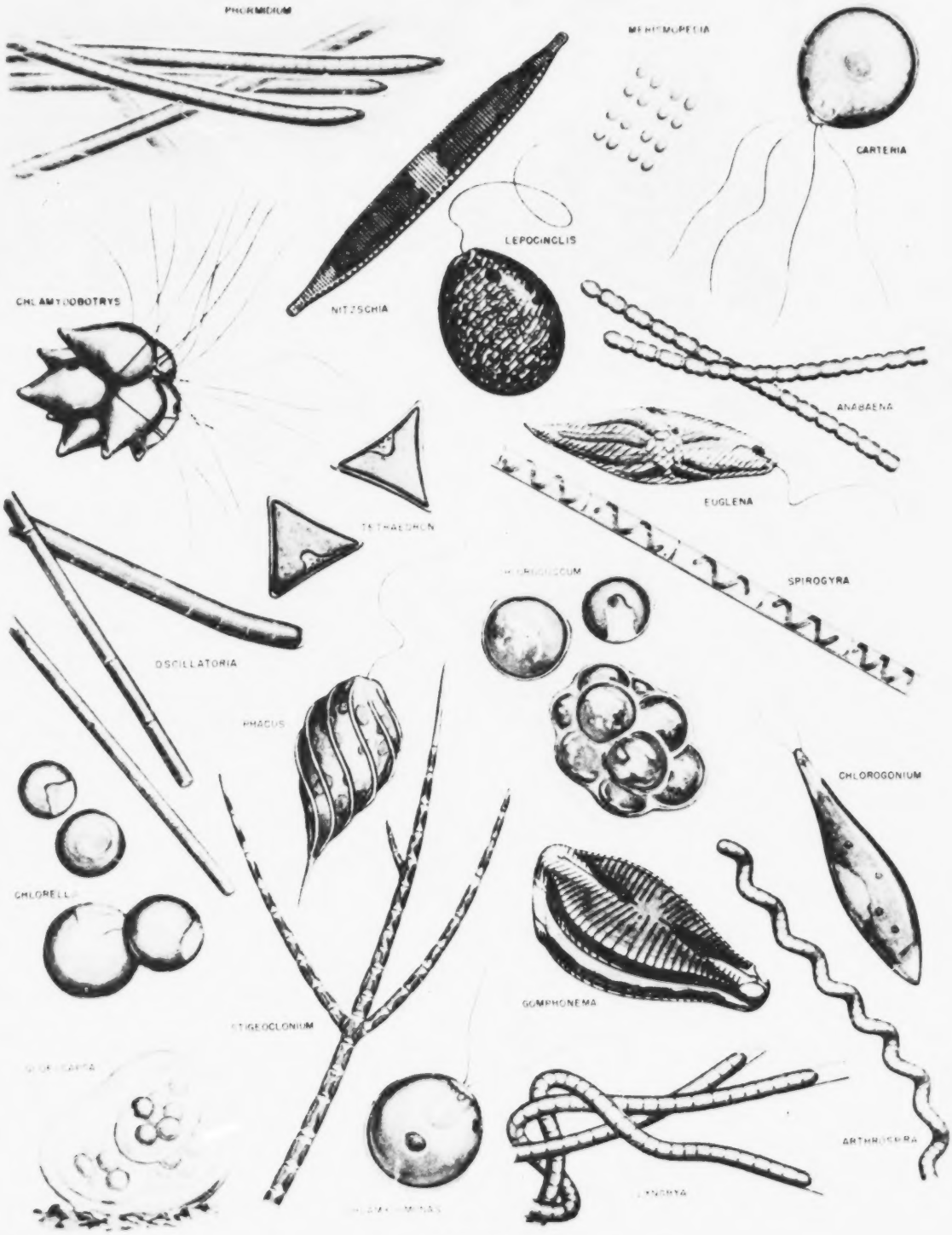


FIGURE 3

FIGURE 4

1 2 3 4 5

NONEMERGENT PLANTS

1. WATER MILFOIL, MYRIOPHYLLUM EXALBESCENS
2. COONTAIL, CERATOPHYLLUM DEMERSUM
3. WILD CELERY, VALLISNERIA AMERICANA
4. PONDWEED, POTAMOGETON CRISPUS
5. LARGE LEAF PONDWEED, POTAMOGETON AMPLIFOLIUS

FILAMENTOUS SEWAGE BACTERIUM, SPHAEROTILUS NATANS
ON GILL NET AFTER SUBMERSION

FIGURE 5

GILL NET BEFORE SUBMERSION

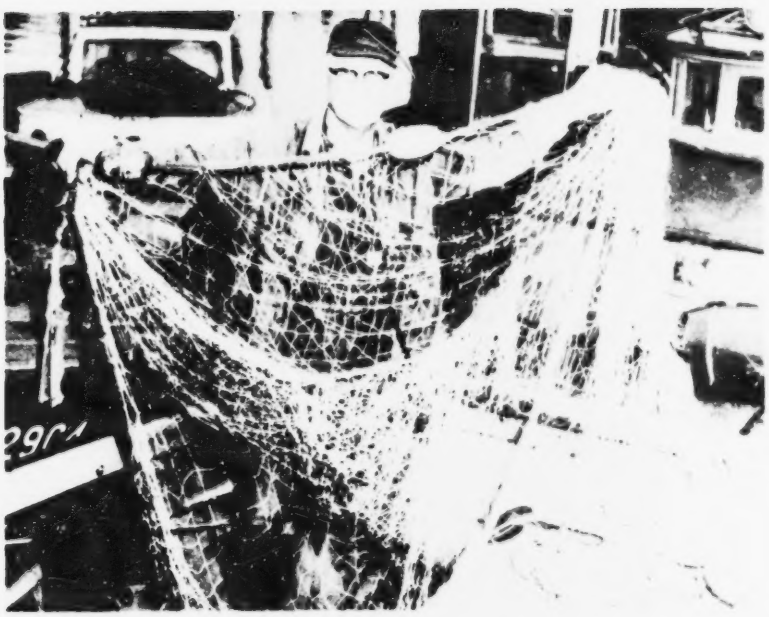
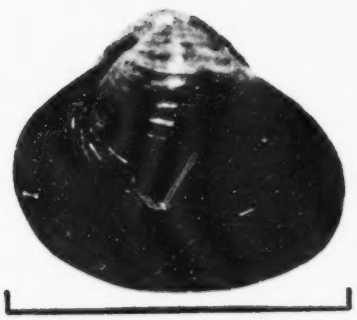


FIGURE 6

ASIATIC CLAM, CORBICULA FLUMINEA



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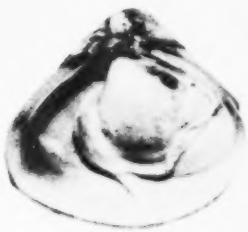


FIGURE 7

ASIATIC CLAMS IN CONDENSER COOLER
UNIT FROM TRACY PUMPING STATION, CALIFORNIA

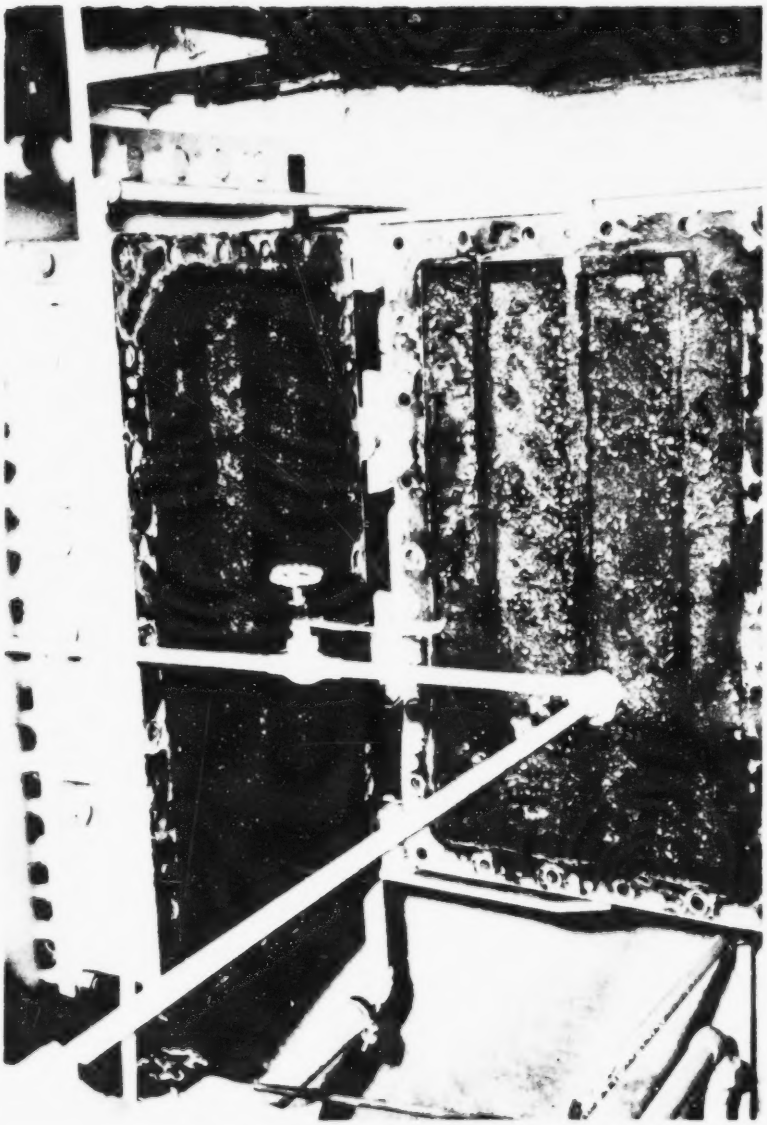
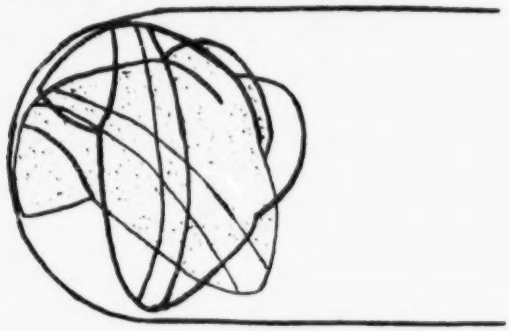


FIGURE 8

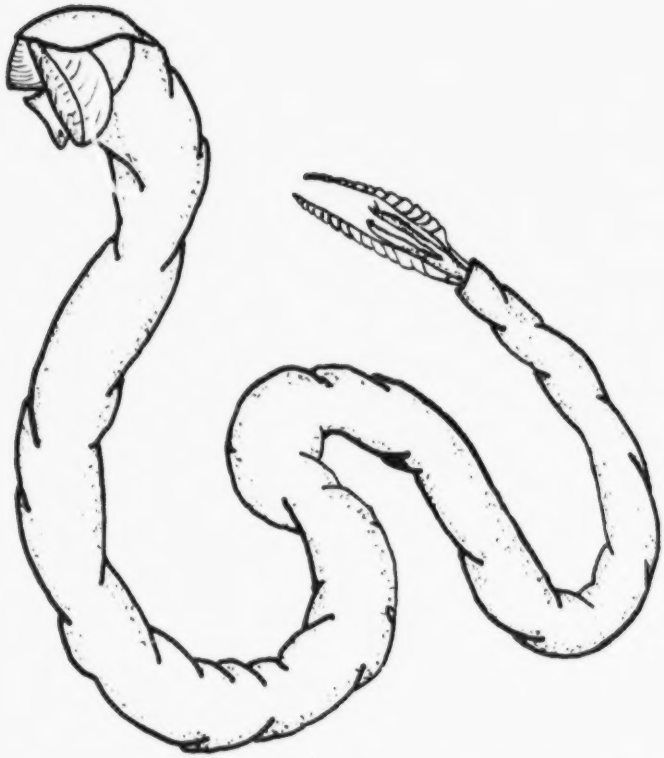
ASIATIC CLAMS FROM CONDENSER COOLER
UNIT OF TRACY PUMPING STATION, CALIFORNIA

FIGURE 9

DIAGRAM OF A WOOD BORING CLAM (SHIPWORM), TEREDINIDAE



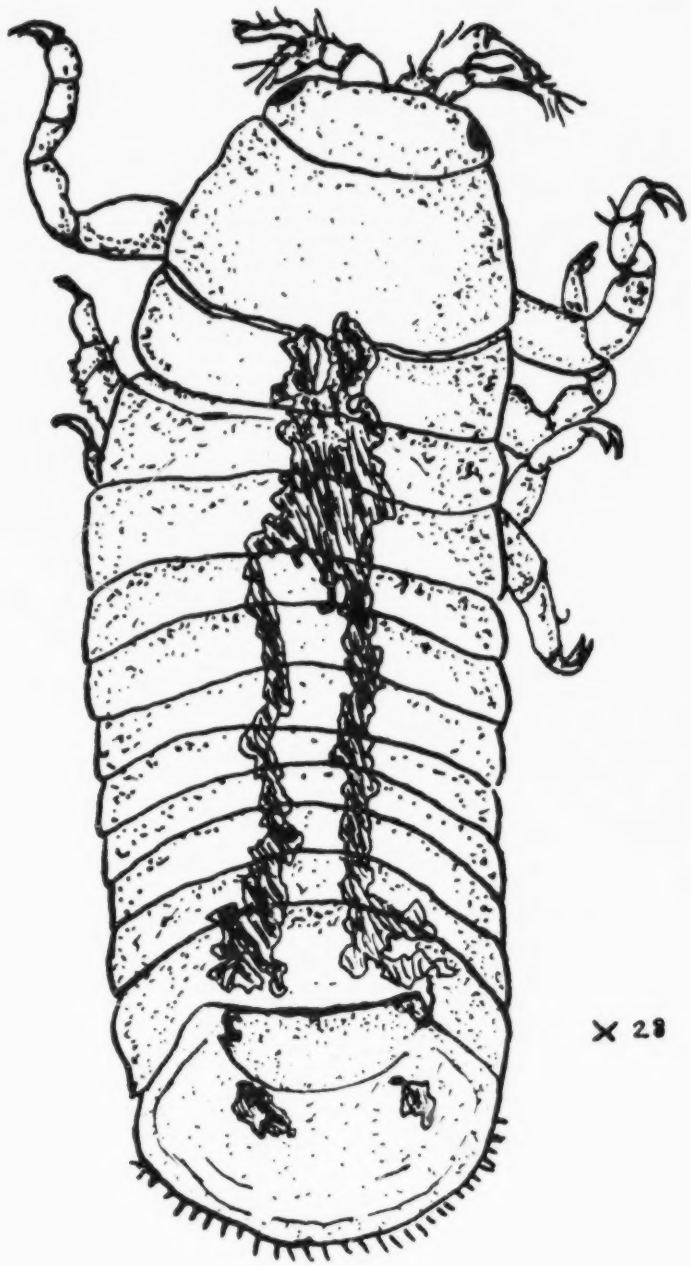
Diagramatic drawing of a Teredinidae shell in the burrow, to show two positions in boring (Lateral view).



Diagramatic drawing of an entire Teredinidae, showing relative position of shells and pallets (Lateral view). (Clench & Turner 1946)

FIGURE 10

DIAGRAM OF WOOD BURROWING ISOPOD, LIMNORIA



Limnoria (dorsal view).
(After Hoek 1893).

FIGURE II

54

WOOD BORING CLAM (SHIPWORM), TEREDINIDAE,
BURROWS IN SAN FRANCISCO BAY PILING CROSS SECTION

FIGURE 12

WOOD BURROWING ISOPOD, LIMNORIA,
BURROWS IN WOODEN BLOCK

FIGURE 13

WOOD BORING CLAM (SHIPWORM), TEREDINIDAE, BURROWS IN SECTION OF BLOCK SUSPENDED IN SAN FRANCISCO BAY

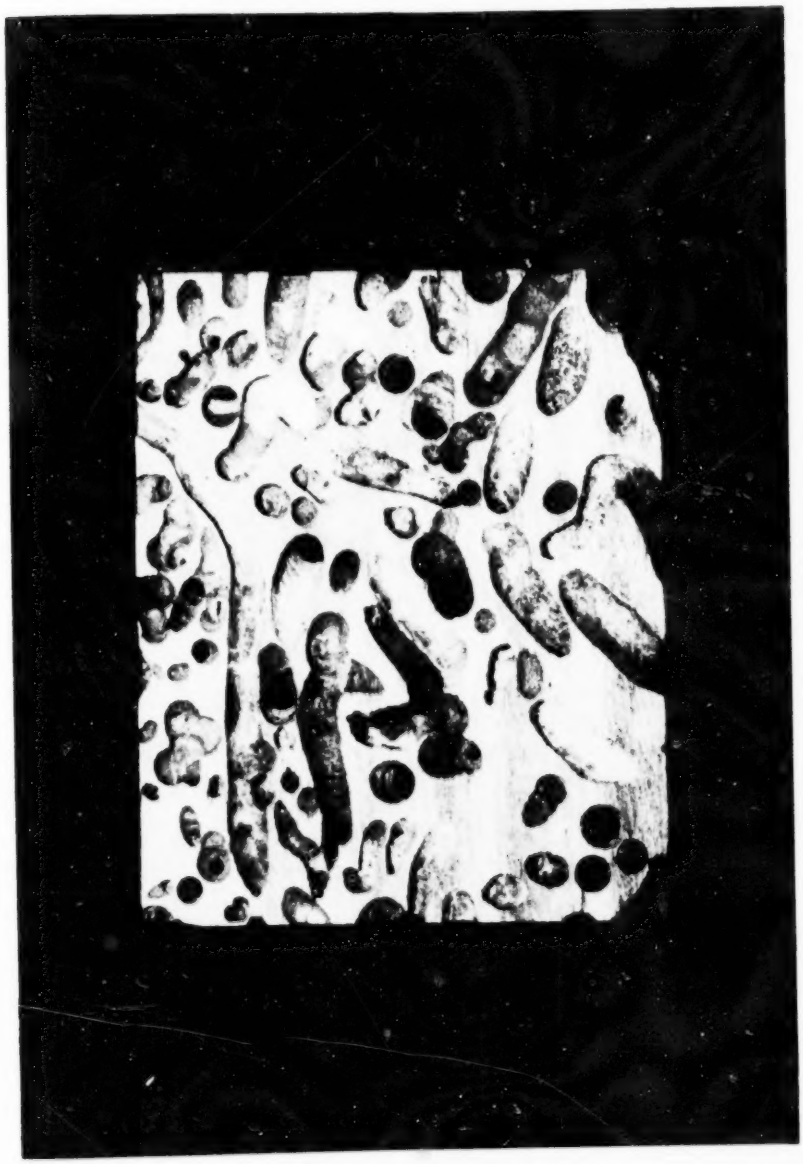
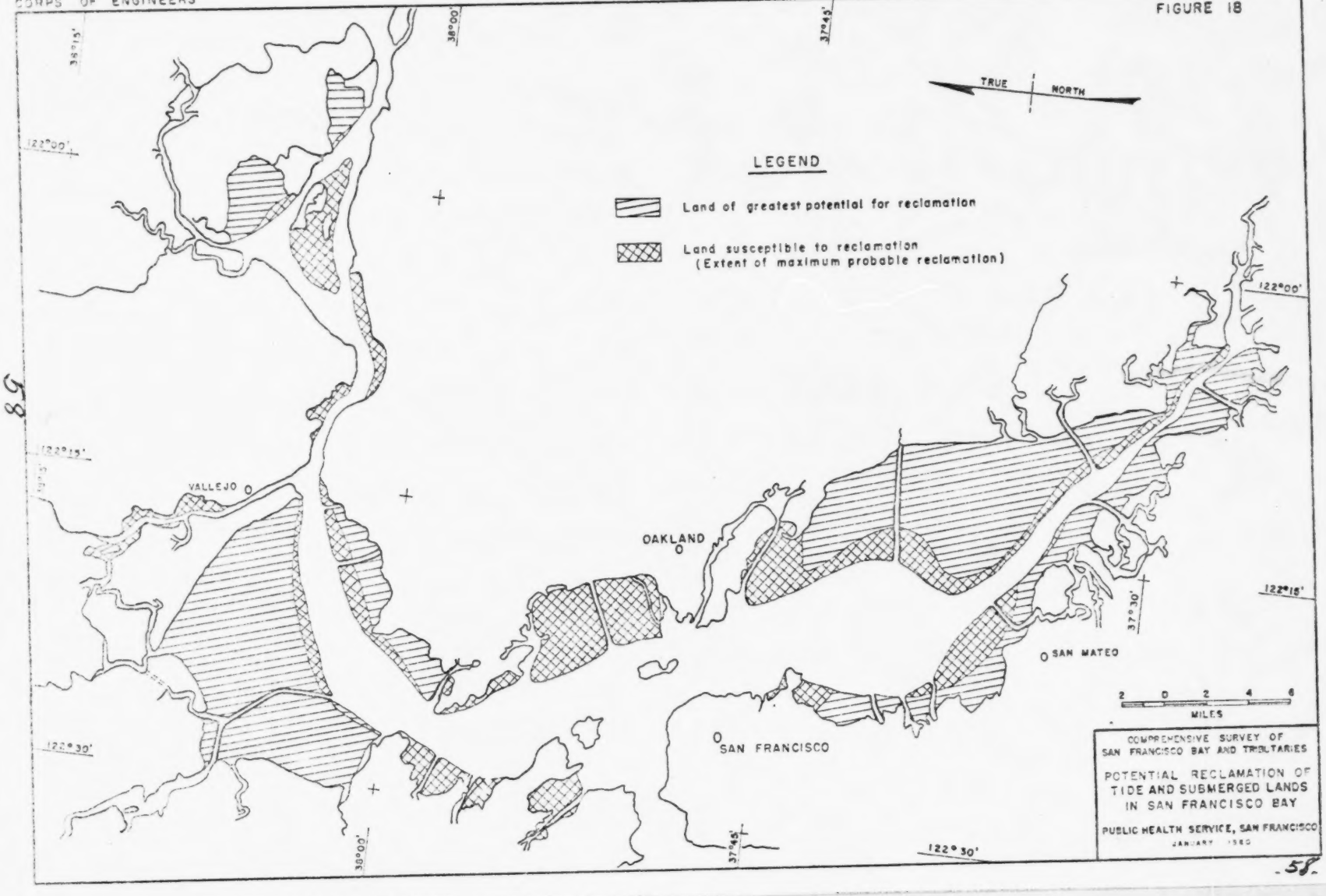


FIGURE 14

U.S. ARMY

CORPS OF ENGINEERS

FIGURE 18

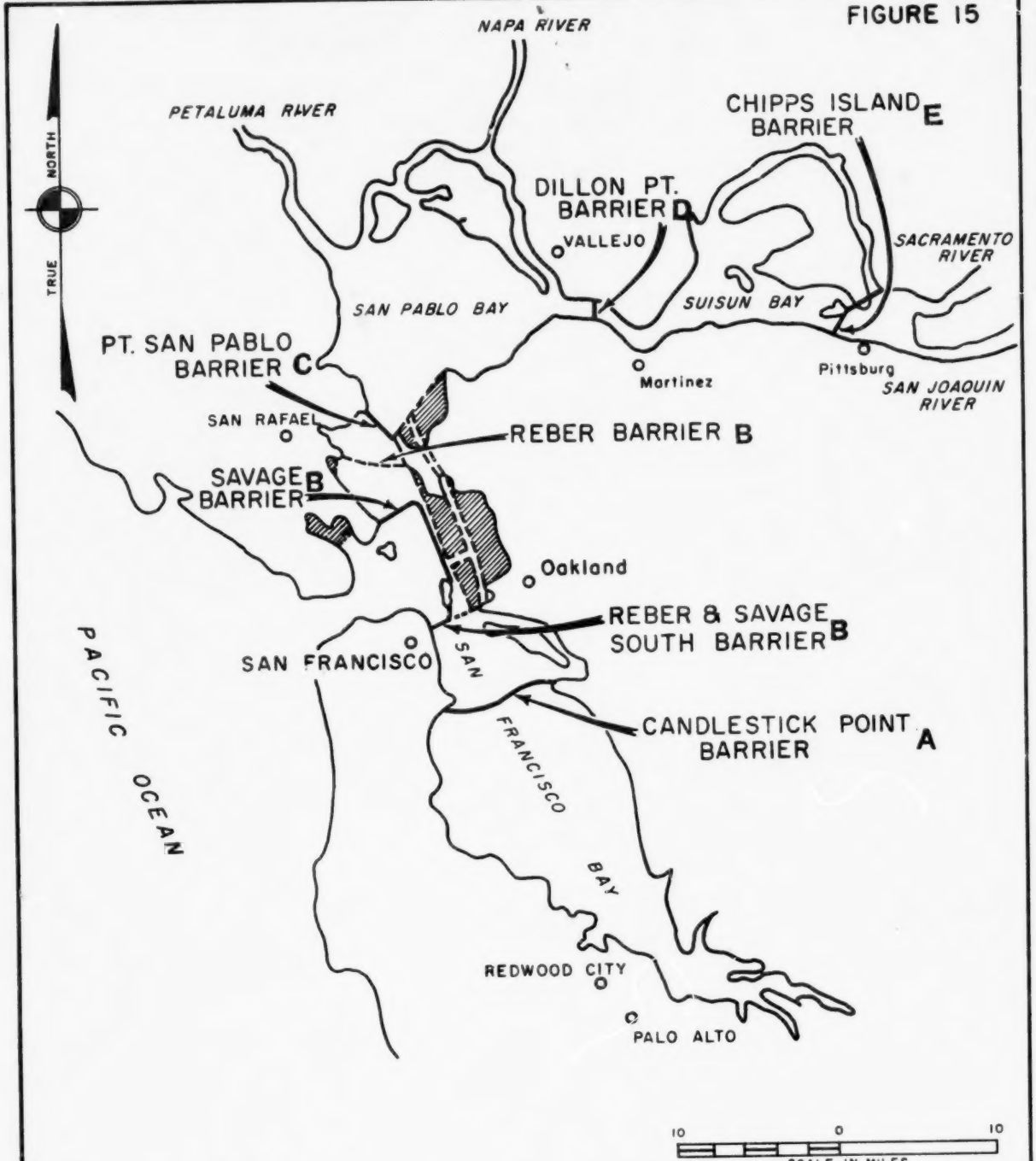


89

58

CORPS OF ENGINEERS U.S. ARMY

FIGURE 15



LEGEND

- Reber Fill Areas
- Reber Plan Barriers
- Barrier Plans as Noted

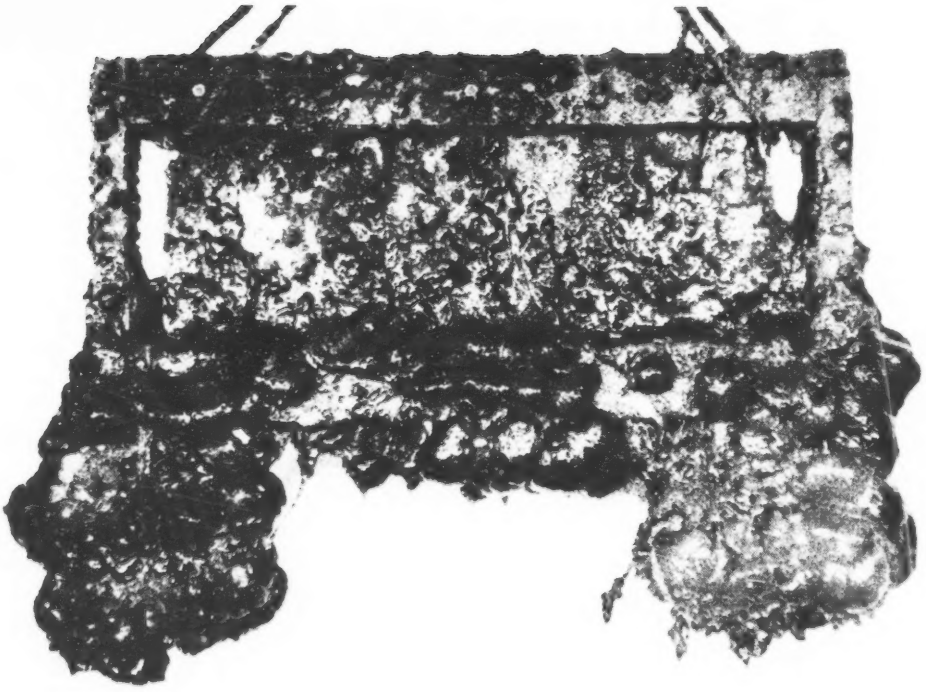
COMPREHENSIVE SURVEY OF
SAN FRANCISCO BAY AND TRIBUTARIES

LOCATION OF PROPOSED BAY BARRIERS

PUBLIC HEALTH SERVICE, SAN FRANCISCO

IN SHEETS SHEET NO.
U.S. ARMY ENGINEER DIST., SAN FRANCISCO, C. OF E.
DRAWN: A.L.R. FILE NO.
TRACED: I.M.H. TO ACCOMPANY REPORT
CHECKED J.F. DATED: JAN. 1960

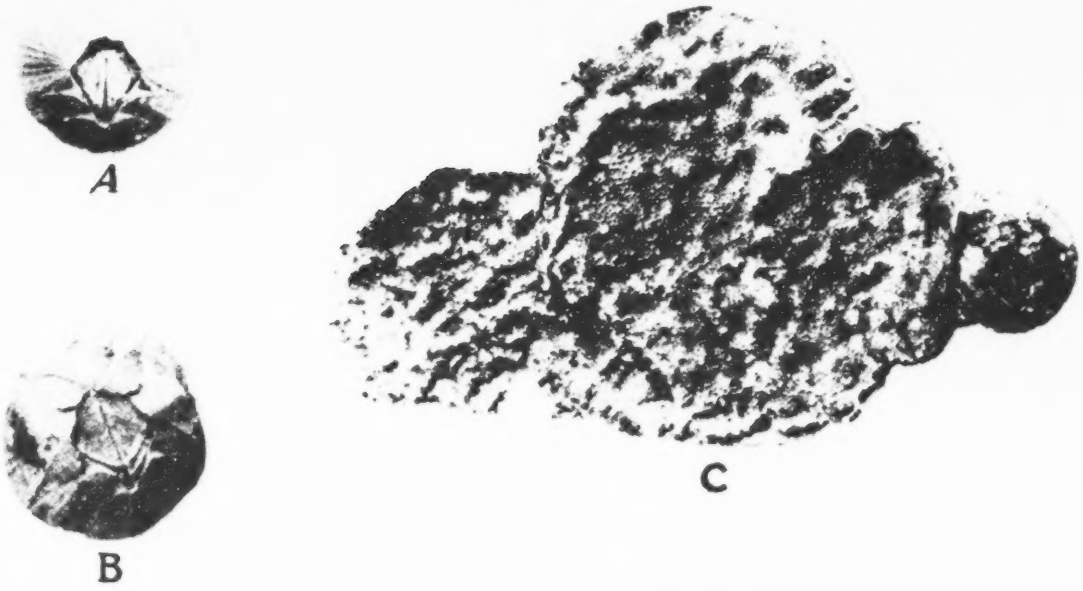
FOULING ORGANISM MASS ATTACHED TO PANELS;
LARGE CLUMPS ARE TUNICATES (SEA SQUIRTS)



B

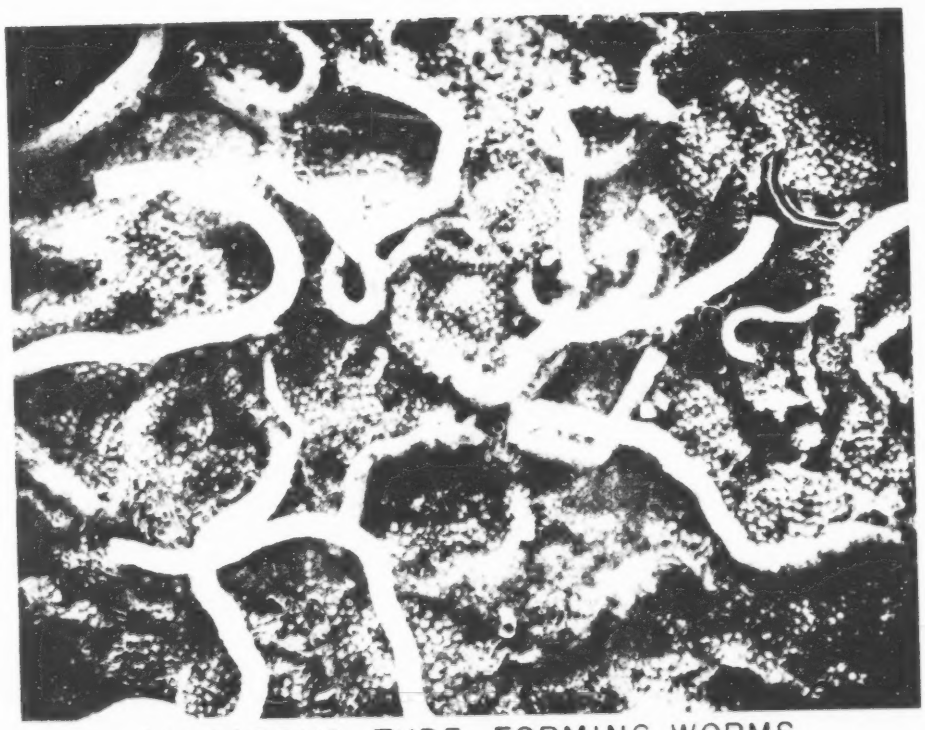
FIGURE 16

FOULING ORGANISMS



A–B. BARNACLES

C. BRYOZOANS



CALCAROUS TUBE-FORMING WORMS,
GROWING OVER CALCAROUS SESSILE BRYOZOANS

FIGURE 17

SPRAYING EQUIPMENT IN OPERATION
FOR SMALL SCALE TREATMENT

FIGURE 19

SPRAYING EQUIPMENT IN OPERATION
FOR LARGE SCALE TREATMENT

FIGURE 20